SURFACE TEXTURE PARAMETERS FOR FLAT GRINDED SURFACES

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Abstract. The given paper is focused on the analyses of surface roughness since this particular indicator of technical characteristics of the product plays the decisive role when determining the quality of component and potential service properties of the surface. As we know, during recent years research of the roughness parameters has reached a new level and it is connected with the emergence of new equipment for the 3D measurement of roughness and introduction of the new standard ISO 25178-2:2012, describing 39 parameters of surface texture for exact determination of properties of a definite surface. In view of the fact that treatment with abrasives grains is a very widely used and precise method of final treatment of components, the paper researched surfaces treated by flat grinding at different component feeding rate. As a result of the research topographies of four flat grinded surfaces were obtained and their processing – filtration using a special software μUltra was carried out. For the determination of the properties of flat grinded surfaces a mathematical model of roughness was developed, texture parameters were analyzed and also their relation to the cutting conditions was established.

Keywords: surface texture, flat grinding, wear resistance, adhesion.

Introduction

One of the main tasks in mechanical engineering is to ensure high quality and efficient work of the system MFTW (machines, fixtures, tools and work pieces). For this it is necessary to ensure precise shape, sizes, tolerances, roughness and also mechanical and technical properties of MFTW elements, what can be achieved applying proper treatment technologies.

As we know, each component, depending on operational properties must possess definite features, for example, wear resistance, corrosion resistance, heat conduction, ability to retain lubricants and coatings and also to ensure the required contact with other surfaces. The texture parameters, namely roughness, to a greater or smaller degree can help in determining the surface properties, which will give a possibility for production engineers to choose the required cutting regimes.

In order to determine roughness parameters equipment is used, the operation principle of which can be based either on contact or non-contact methods. The work examines the operation principle of the profilograph – profilometer Taylor Hobson Talysurf Intra 50, precise measuring equipment for the determination of roughness by the contact method. The given equipment ensures determination of 3D parameters of roughness due to a special 3 dimensional measuring system. The 3D roughness parameters contrary to profile parameters [1; 2] provide information about the location of roughness in the space, what allows to determine the presence of actual hollows and peaks of the surface.

The given paper presents an analysis of flat grinded surfaces, the characteristic properties of the roughness structure which have not been investigated completely, but are of great interest in the field of mechanical engineering, because components for fit, fixtures for fixing samples on machine-tools, sealing elements, surfaces for coatings deposition are treated on flat grinding machines. The analyses of the given type of surfaces is crucial to ensure efficient operation of the MFTW system.

The following paragraphs will give information about the samples to be investigated, equipment used in the experiment for the roughness measurement and analyses of the obtained data.

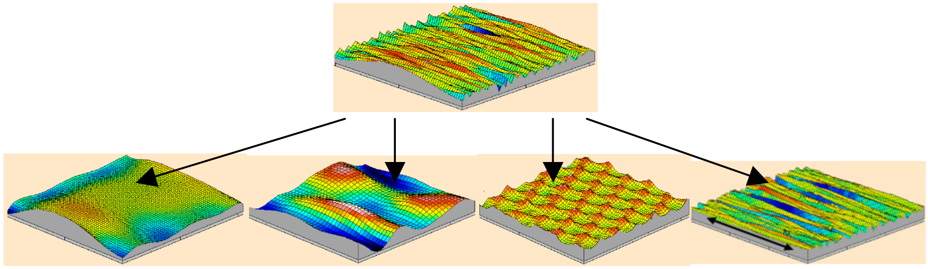
Flat grinded samples and measuring equipment

To carry out the experiment for determination of the roughness parameters the Rugotest 104 sample (Fig. 1) made of corrosion resistant nickel was chosen with hardness close to structural steel. The given sample has 8 surfaces treated at different feed rates. For roughness determination there were surfaces No.1, 3, 6, 8 chosen.

Modern profilograph – profilometer Taylor Hobson Talysurf Intra 50 with resolution 16 nm was chosen. Measurement error constitutes 2% of the measurement result. The operation principle of the given equipment is based on the movement of a needle with 2 μm radius along the investigated surface, copying the contours of microirregularities. The main elements of the measuring equipment are: a rod with a diamond needle and a sensor transforming electrical voltage into vertical movement of the needle.

Fig. 1. **Flat grinded sample Rugotest 104**

The measurement results initially are preserved in the form of a topography (surface texture), and afterwards by the help of computer software µultra the given topography is being filtrated and the roughness parameters are determined automatically. Filtration is needed in order to separate the shape and waviness appearing as a result of incorrect treatment conditions, vibrations, thermal processes etc. (Fig. 2).

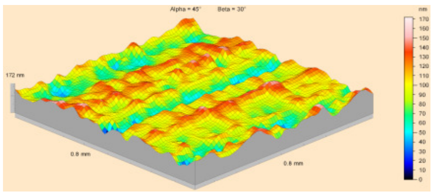
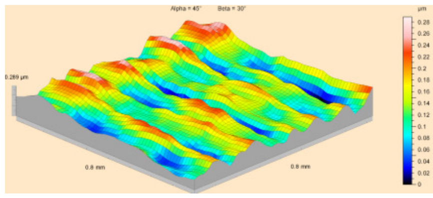


a) b) c) d)

Fig. 2. **Surface texture:** a – shape, b – waviness, c - roughness, d – direction of roughness [3]

Mathematical model of roughness of flat grinded surface

As a result of the experiment topographies of four surfaces were obtained (Fig.3), which show that surface structure after flat grinding have parallel accumulations of shallow micro-scratches made by abrasive grains located in the periphery of the grinding circle. Grains used in the cutting process have different degree of wear; because of this the surface roughness is not homogenous.

a)  b) 

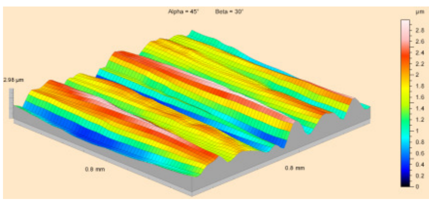
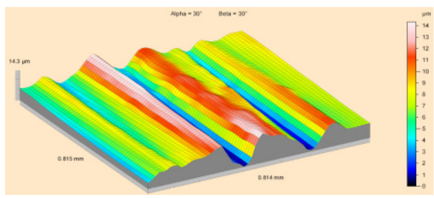
c)  d) 

Fig. 3. **Topography of roughness of surfaces No.1 (a), No.3 (b), No.6 (c), No.8 (d)**

The obtained topographies show also the oriented structure of roughness, i.e. surface irregularities are oriented towards a definite direction – for surfaces No.6 andNo.8 towards the Y axis, and for surface No.1 – towards the X axis. The given structure represents the anisotropy of the surface, but irregular location of micro-irregularities - its random character.

According to the literature source [4] the mathematical model of rough surface includes the correlation function and density distribution of irregularities heights. The autocorrelation function determines the measure of overlapping of two random functions. If the duplicate shifted by the surface is identical to the original surface, then ACF will be equal to 1.00. If in the duplicate shifted by the surface all peaks coincide with the hollows of the original surface, then ACF will be equal to -1.00 [5]. In other words, ACF can be defined as a function identifying the similarity of surface textures at a definite distance from the original surface. The autocorrelation functions and distribution of ordinates of flat grinded surfaces look as follows (Fig. 4).

a)

b)

c)

d)

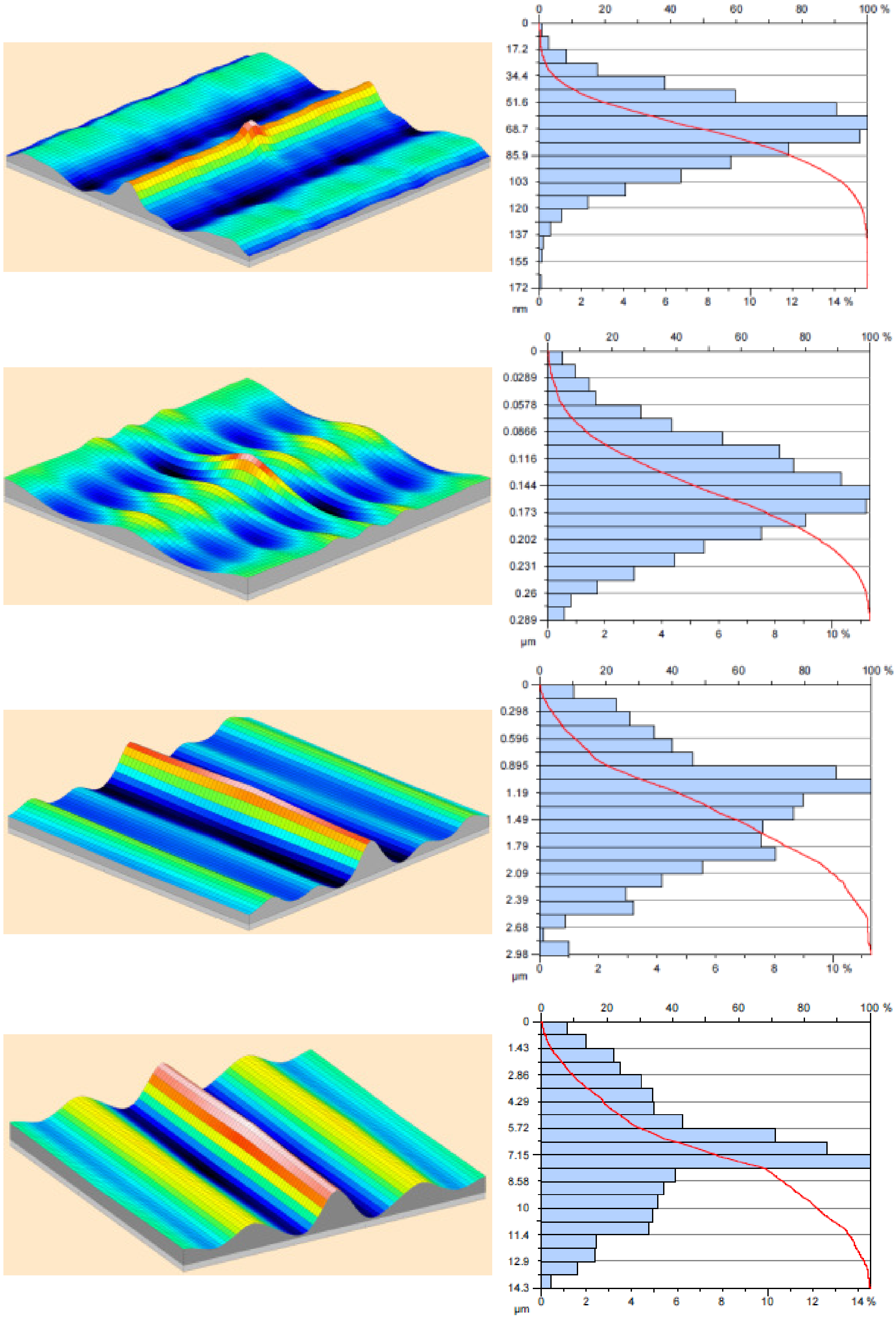


Fig. 4. **Correlation functions and ordinate distribution histograms of surfaces No.1 (a), No.3 (b), No.6 (c), No.8 (d)**

Fig.4 displays that all four autocorrelation functions are exponential with decaying oscillations that indicates the presence of the oscillatory processes in the system. Ordinates distribution of the surface is random and is almost identical to the normal distribution law, as evidenced by the tendency of ordinates to cluster around the center and equal probability of positive and negative deviations from the center.

3D roughness parameters of flat grinded surfaces

The Standard ISO 25178-2:2012 [6] comprises 6 groups of parameters – height, functional, spatial, hybrid, functions/related and miscellaneous parameters. For determination of the functional properties of surfaces one should not limit to the analyses of only the height parameter *Sa* (*Ra*) since it does not comprise information on the shape of micro-irregularities. It means that at similar values of *Sa* one surface can have explicit sharp peaks but another surface - groups of micro-peaks, forming flat peaks of roughness. Table 1 includes values of the necessary parameters for determination of the functional properties of the investigated surfaces. The roughness parameters were chosen according to the authors' researches in references [3].

Table 1

Roughness parameters of surfaces No.1, No.3, No.6, No.8 of sample Rugotest 104

Parameters	1	3	6	8	Measuring unit
Sa	0.0178	0.0418	0.482	2.26	μm
Ssk	-0.286	0.104	-0.103	0.0127	-
Sku	3.2	2.77	2.58	2.67	-
Sz	0.130	0.267	2.76	10.5	μm
Str	0.127	0.172	0.106	0.106	-
Sdr	7e-005	0.000254	0.0277	0.464	%
Spk	0.0103	0.0214	0.315	1.16	μm
Svk	0.0127	0.0296	0.359	1.11	μm
*Smr*1	9.67	7.93	7.36	7.88	%
*Smr*2	90.4	90.1	86.9	88.5	%
Vv	6.6e-005	0.000149	0.00135	0.00696	$mm^3 \cdot mm^{-2}$
Vm	0.000101	0.000139	0.00162	0.00734	$mm^3 \cdot mm^{-2}$
Vmp	1.37e-005	2.3e-005	0.00026	0.00124	$mm^3 \cdot mm^{-2}$
Vmc	7.39e-005	0.000103	0.0012	0.00547	$mm^3 \cdot mm^{-2}$
Vvc	2.61e-005	6.59e-005	0.000748	0.0038	$mm^3 \cdot mm^{-2}$
Vvv	2.83e-006	5.61e-006	6.36e-005	0.000322	$mm^3 \cdot mm^{-2}$

For wear resistance determination the height parameters of roughness *Sa, Spk, Ssk*, spatial parameter *Str* and functional – *Vmp* were chosen. Parameter *Ssk* is needed for determination of roughness asymmetry. Provision of the bearing surface and correspondingly contact area will be achieved at negative values of *Ssk* since the number of sharp peaks will be insignificant. In the given case the asymmetry values of all 4 samples are about zero, which shows even distribution of micro-peaks in relation to the middle line. Parameter *Str* helps to determine isotropy of the surface, which ensures uniform distribution of load along the whole surface; Value of the parameter *Str* should be greater than 0.5. In the given case the values of the parameter *Str* only prove the data of topography, according to which explicit anisotropy of surfaces was determined; the value of the parameter *Str* in all cases is close to 0.1.

In turn, the parameter *Vmp* (material void volume) allows to determine detail wear during the initial stage of exploitation – running-in. Fig. 5 presents peaks of micro-irregularities, which will be rapidly removed from the surface during the initial contacting. In the given case one can observe a trend that with the increase of mean arithmetic height of roughness material volume of peaks, removed from the surface, increases proportionally.

Wear of the surface can also be predicted using the value of the parameter *Spk*, which shows the height of the most explicit peaks. With the increase of the feed speed the values of the given parameter are also growing.

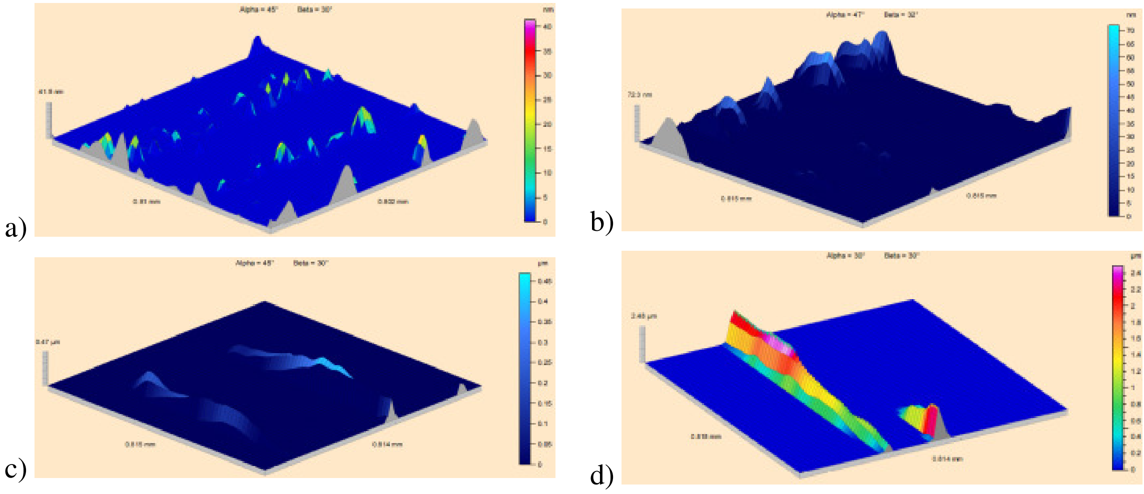


Fig. 5. **Volume of surfaces' No.1 (a), No.3 (b), No.6 (c), No.8 (d) separated material during running-in stage**

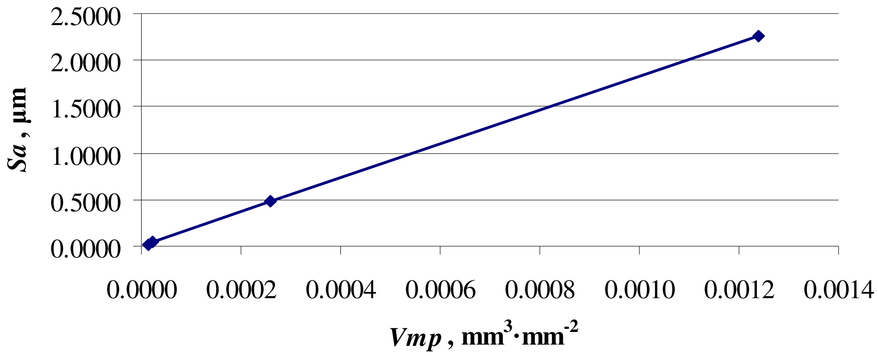


Fig. 6. **Dependence between parameters *Sa* and *Vmp***

Not the least of the properties of flat grinded surfaces is retention of lubricants, which is characterized by the necessary depth of surface valleys to enable for the penetration. In order to determine the void volume parameters *Vv, Vvc* and *Vvv* were used. The void volume before the running-in stage is characterized by the parameter *Vv*, the value of which for the surface No.1 is 100 times less than for the surface No.8. After the running-in stage the void volume of each surface has diminished about twice, what is proved by the values of the parameter *Vvc*, but after the stage of normal wear the void volume for retaining lubricants is preserved only on the surface No.8, treated at the fastest feed rate (Fig. 7).

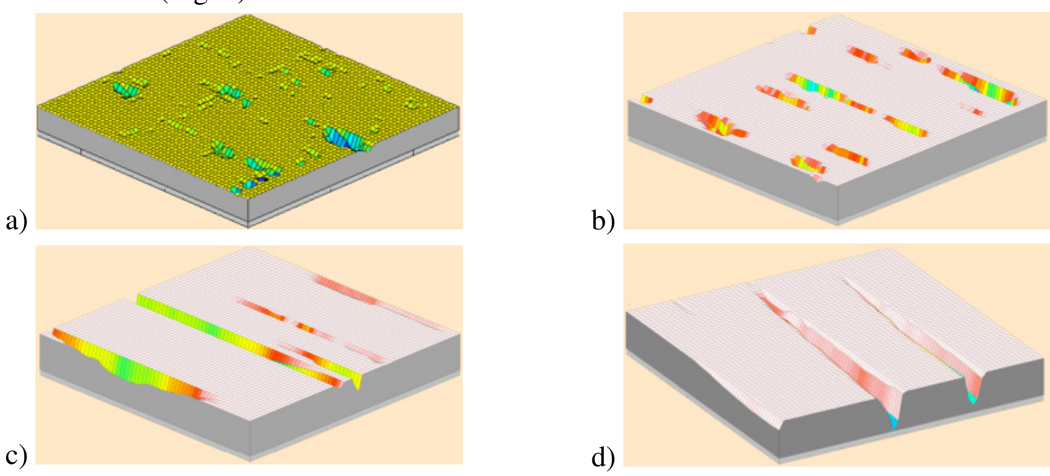


Fig. 7. **Roughness of surfaces No.1 (a), No.3 (b), No.6 (c), No.8 (d) after the stage of normal wear**

Flat grinded surfaces are characterized also by the ability to retain coatings, the so-called adhesion [7]. In the given case rough surfaces present bigger interest because their area will ensure stronger connection with the coating. For this purpose it is necessary to determine the value of the parameter *Sa*. Since for the surface No.8 the parameter *Sa* = 2.26 µm, but with the decrease of the speed of the feed rate the values of arithmetic mean height are falling abruptly. In order to understand how big the surface area will be it is essential to determine the values of the parameter *Sdr*, which comprises information about the relation between the actual area and nominal area of the surface. Table 1 shows that with the increase of the value of the parameter *Sa* the area of rough surface is also increasing. Additional information about the dependence of parameters *Sa* and *Sdr* is given by the chart in Fig. 8, which shows that at small values of *Sa* the surface area practically is not changing, but at a sharp increase of mean arithmetical height of the surface adhesion is considerably changing in size.

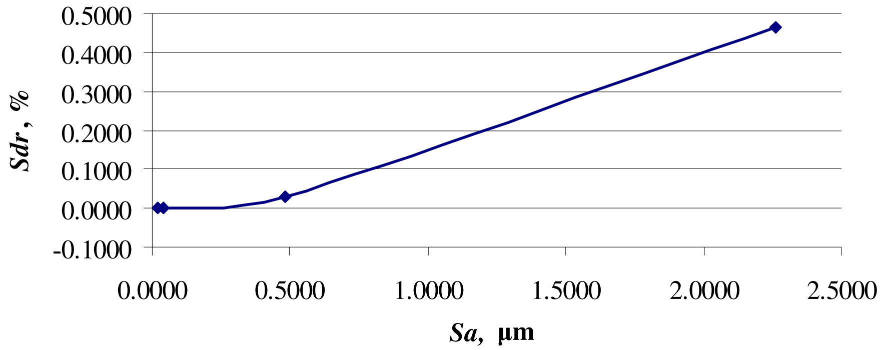


Fig. 8. **Dependence between parameters *Sa* and *Sdr***

An additional precondition for ensuring the adhesion of coating is the presence and shape of hollows. Therefore, attention should be paid to the surface with deep and sharp valleys in order to exclude the risk of air pockets, which weaken molecular connections between the covering and the surface. So, the value of the roughness parameter *Sku* must be known, which expresses the kurtosis of 3D roughness. For all four surfaces the values of the given parameter are actually identical and they are varying within the range of 3, what proves the presence of a definite number of sharp form hollows.

Conclusions

1. The mathematical model of flat grinded surfaces includes an exponential correlation function with decaying oscillations and normal distribution density of surface ordinates.
2. The wear resistance of the surface depends on its isotropy, distribution of microirregularities heights in relation to the middle line and material volume, described by parameters *Str, Ssk* and *Vmp*. The values of parameters *Ssk* and *Vmp* are growing because of the feed rate increase.
3. The property of surface to retain lubricants is characterized mainly by void volume (*Vv, Vvc, Vvv*) in the different stages of exploitation, but coating adhesion is ensured by high values of the parameter *Sa*, and respectively by the area of substrate adhesion with the coating (*Sdr),* and also by the shape of voids (*Sku),* which should be possibly flat.

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